

*D. L. ORLOVSKIY, A. M. KOPP, V. Y. KONDRATIEV***DEVELOPMENT OF A MODEL AND A SOFTWARE SOLUTION TO SUPPORT THE ANALYTICAL DASHBOARDS DESIGN PROBLEM**

This research paper considers the problem of dashboard design as part of the Business Process Management lifecycle, where it is become necessary to monitor and control the current state of the organizational business processes. Therefore, designed dashboards should fully correspond to the features of the considered business processes, such as Key Performance Indicators and possible stakeholders, which are considered here as users of the developed Business Intelligence dashboard application. At the same time, according to the state-of-the-art in the field of data visualization, it is required to choose data visualization techniques, which are clear, easy interpretable, space efficient, attractive, and legible. In general, the dashboard design problem requires placing various visualization tools in a relatively small place, such as a screen of a computer, a laptop, a tablet, or even a smart phone, while keeping them accessible and easy to understand. At first, as part of the related work review and analysis, we have considered the core architecture of the dashboards and reporting applications. It is outlined that modern dashboards might use various big data chunks, such as databases of enterprise information systems of different types, spreadsheets data, and even unstructured documents. In order to summarize all the raw data from these data sources, the Data Warehouse should be built and, moreover, it should correspond to the metrics and indicators of business processes that should be demonstrated on a dashboard. We have also considered main principles, common mistakes, and graphs and charts that might be used to design a dashboard for business analytics purposes. Using the existing research in this field, the levels of informativeness were defined for each visualization tool, as well as the best practices of mapping various data types to graphs and charts are outlined. Proposed model of the dashboard design is based on the mathematical optimization. It is used to provide recommendations on which visualization tool should be used to display a certain Key Performance Indicator on a dashboard that corresponds to a certain user role. Development and usage of the software solution that implements the proposed model is outlined, as well as the obtained results of validation of the proposed software solution are shown and discussed.

Keywords: business process management, business intelligence, key performance indicator, business analytics, dashboard, data visualization indicators.

*Д. Л. ОРЛОВСЬКИЙ, А. М. КОПП, В. Ю. КОНДРАТЬЄВ***РОЗРОБКА МОДЕЛІ ТА ПРОГРАМНОГО РІШЕННЯ ДЛЯ ПІДТРИМКИ ВИРІШЕННЯ ЗАДАЧІ ФОРМУВАННЯ АНАЛІТИЧНИХ ПРИЛАДОВИХ ПАНЕЛЕЙ**

У даній роботі розглядається проблема проектування аналітичних приладових панелей як складової частини життєвого циклу управління бізнес-процесами, в рамках якого необхідно виконувати моніторинг та контроль поточного стану організаційних бізнес-процесів. Тому розроблені аналітичні панелі повинні повністю відповідати особливостям розглянутих бізнес-процесів, наприклад, ключових показників ефективності та можливих зацікавлених сторін, які в даній роботі розглядаються в ролі користувачів розробленого застосування інтелектуального аналізу даних, що реалізує необхідні приладові панелі. У той же час, згідно з останніми дослідженнями у галузі візуалізації даних, необхідно вибирати методи візуалізації даних, які є чіткими, легко інтерпретованими, ефективними з точки зору розміщення, привабливими та розбірливими. Загалом проблема проектування приладової панелі вимагає розміщення різних інструментів візуалізації у відносно невеликому місці, наприклад, на екрані комп'ютера, ноутбука, планшета чи навіть смартфона, зберігаючи їх доступними та зрозумілими. Перш за все, в рамках огляду та аналізу існуючих джерел, було розглянуто основну архітектуру аналітичних панелей та застосувань звітування. Зазначається, що сучасні аналітичні панелі можуть використовувати різні великі масиви даних, такі як бази даних корпоративних інформаційних систем різного типу, дані у форматі електронних таблиць і навіть неструктуровані документи. Для узагальнення всіх необроблених даних із цих джерел даних необхідно застосовувати сховища даних, структура яких повинна відповідати метрикам та показникам бізнес-процесів, які необхідно демонструвати на приладовій панелі. Також було розглянуто основні принципи, поширені помилки, графіки та діаграми, які можуть бути використані під час проектування приладової панелі для задач бізнес-аналітики. На основі існуючих досліджень у цій галузі було визначено рівні інформативності для кожного інструменту візуалізації, а також розглянуто найкращі практики відображення різних типів даних за допомогою графіків та діаграм. Запропонована модель побудови приладової панелі базується на задачі математичної оптимізації. Дана модель використовується для надання рекомендацій щодо того, який інструмент візуалізації повинен використовуватися для відображення певного ключового показника ефективності на приладовій панелі, що відповідає певній ролі користувача. Розглянуто інформаційну технологію, що реалізує запропоновану модель, а також отримані результати перевірки працездатності запропонованого програмного рішення та їх обговорення.

Ключові слова: управління бізнес-процесами, інтелектуальний аналіз даних, ключовий показник ефективності, бізнес-аналітика, приладова панель, індикатори візуалізації даних.

*Д. Л. ОРЛОВСКИЙ, А. М. КОПП, В. Ю. КОНДРАТЬЕВ***РАЗРАБОТКА МОДЕЛИ И ПРОГРАММНОГО РЕШЕНИЯ ДЛЯ ПОДДЕРЖКИ РЕШЕНИЯ ЗАДАЧИ ФОРМИРОВАНИЯ АНАЛИТИЧЕСКИХ ПРИБОРНЫХ ПАНЕЛЕЙ**

В данной работе рассматривается проблема проектирования аналитических приборных панелей в качестве составной части жизненного цикла управления бизнес-процессами, в рамках которого необходимо выполнять мониторинг и контроль текущего состояния организационных бизнес-процессов. Поэтому разработанные аналитические панели должны полностью соответствовать особенностям рассматриваемых бизнес-процессов, например, ключевых показателей эффективности и возможных заинтересованных сторон, которые в данной работе рассматриваются в качестве пользователей разрабатываемого приложения интеллектуального анализа данных, реализующего необходимые приборные панели. В то же время, согласно последним исследованиям в области визуализации данных, необходимо выбирать методы визуализации данных, которые являются четкими, легко интерпретированными, эффективными с точки зрения размещения, привлекательными и разборчивыми. В общем виде, проблема проектирования приборной панели требует размещения различных инструментов визуализации в относительно небольшом месте, например, на экране компьютера, ноутбука, планшета или даже смартфона, сохраняя их доступными и понятными. Прежде всего, в рамках обзора и анализа существующих источников, была рассмотрена основная архитектура аналитических панелей и приложений отчетности. Отмечается, что современные аналитические панели могут использовать различные крупные массивы данных, такие как базы данных корпоративных информационных систем различного типа, данные в формате электронных таблиц и даже неструктурированные документы. Для обобщения всех необработанных данных из этих источников данных необходимо применять хранилища данных, которые, в частности, должны соответствовать метрикам и показателям бизнес-процессов,

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которые необходимо демонстрировать на приборной панели. Также были рассмотрены основные принципы, распространенные ошибки, графики и диаграммы, которые могут быть использованы при проектировании приборной панели для задач бизнес-аналитики. На основе существующих исследований в этой области были определены уровни информативности для каждого инструмента визуализации, а также рассмотрены лучшие практики отображения различных типов данных с помощью графиков и диаграмм. Предложенная модель построения приборной панели базируется на задаче математической оптимизации. Данная модель используется для предоставления рекомендаций относительно того, какой инструмент визуализации должен использоваться для отображения определенного ключевого показателя эффективности на приборной панели, соответствующей определенной пользовательской роли. Рассмотрена информационная технология, реализующая предложенную модель, а также полученные результаты проверки работоспособности предложенного программного решения и их обсуждение.

Ключевые слова: управление бизнес-процессами, интеллектуальный анализ данных, ключевой показатель эффективности, бизнес-аналитика, приборная панель, индикаторы визуализации данных.

Introduction. Today Business Process Management (BPM) is considered as the most popular management approach. Its main idea is to consider organizational activity as the set of interrelated business processes. Each business process includes structured set of tasks that take input resources and produces valuable products and/or services for the particular customer [1]. BPM defines so called lifecycle of business processes. It includes stages related to business process identification and discovery (manually or with the help of Process Mining methods and tools [2]), analysis and redesign (continuous improvement methods, such as Plan-Do-Check-Act – PDCA cycle [3]), implementation (e.g., with the help of Business Process Model and Notation – BPMN standard [4], which further is uploaded into a Business Process Management Suite – BPMS in order to provide automated business process execution [5]), monitoring and control (for this purpose such techniques and tools as scorecards with the set of Key Performance Indicators – KPIs are applied [6], as well as Business Intelligence – BI solutions such as Data Warehouses [7] and Analytical Dashboards [8] are used).

This work focuses on methods and tools that are used on the final stage of BPM lifecycle that deals with the monitoring and control. Thus, the research object is a process of the dashboards design for the business process status analysis. The research subject includes a model and a software solution for the dashboard design for the business process status analysis. The goal of this research is to choose data visualization techniques, which are clear, easy interpretable, space efficient, attractive, and legible. However, the dashboard design problem requires placing various visualization tools in a small place, while keeping them accessible and easy to understand [9].

Related work. While the term “dashboard” itself is originated from the automobile dashboard, in the domain of business analysis it describes a type of user interface which provides views of relevant KPIs. Dashboards are displayed on web pages that use linked data warehouses as data sources (fig. 1). Dashboards typically indicate KPIs that require urgent actions at the top of the page [10].

OLAP (Online Analytical Processing) is a computer-based data processing technology, which serves to provide aggregated multidimensional data arrays (cubes) from big data chunks, such as relational databases, documents, flat files, unstructured data sources etc. OLAP cube is the core technology of any OLAP system. It contains numeric data facts called measures that are consolidated by dimensions along which projection operations, such as aggregation or averaging, can be performed in order to enable analysts to answer business questions [11].

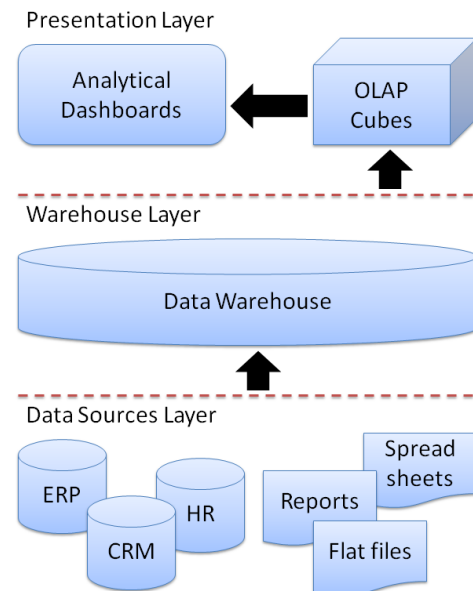


Fig. 1. Simplified view of the dashboards architecture

Whereas considered research domain is not popular enough, the state-of-the-art of the dashboard design was carefully analyzed in paper [12]. Thus, we can focus on three core directions that might help us to solve the considered problem (fig. 2).

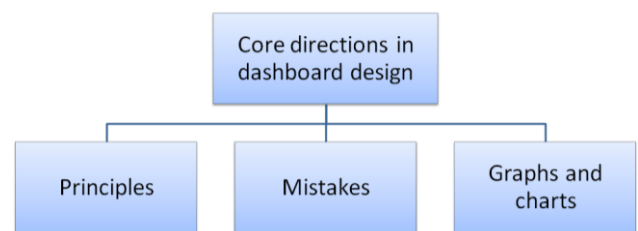


Fig. 2. Core directions in the dashboard design problem

The main principles for the dashboard design include the following [13]:

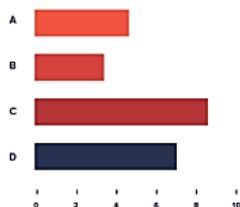
- Selected chart should fit the best a data type of a certain dataset displayed on a dashboard.
- Selected chart should serve its purpose even if it is resized in order to be place into a small place on a dashboard.

The most common mistakes of the dashboard design are related to the choice of inappropriate data visualization tools such as graphs and charts [13]. As the most suitable visualization tools, bar charts, line charts, pie charts, and gauges are considered [14, 15].

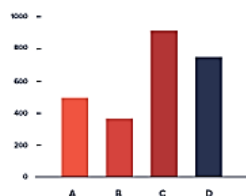
The most informative and popular graphs and charts are the following [15, 16]:

- Bar chart (shown in fig. 3). There are bar charts of different types, such as horizontal, vertical, grouped, and stacked bar charts, which might be used to visualize different indicators.

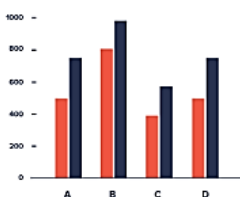
Bar Chart (Horizontal)



Bar Chart (vertical)



Grouped Bar Chart



Stacked Bar Chart

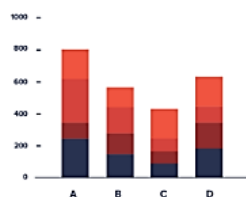
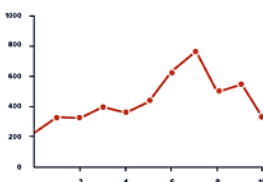


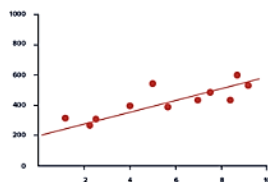
Fig. 3. Horizontal, vertical, grouped, and stacked bar chart examples

- Line chart (shown in fig. 4). These charts might be used to display distributions, trend lines, etc.

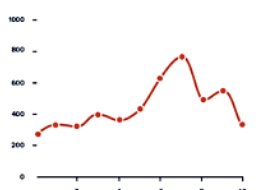
Line Graph



Trendline



Spline Graph



Stepped Line Graph

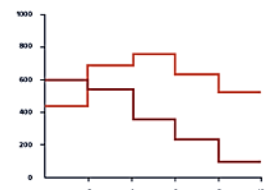


Fig. 4. Line, trend line, spline, and stepped line chart examples

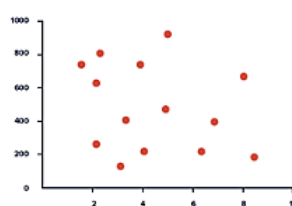
- Bullet graph (shown in fig. 5).



Fig. 5. Bullet graph example

- Scatter chart (shown in fig. 6). As well as other graphs and charts (e.g., line or bar charts), the scatter chart might be used to display three-dimensional (3D) data.

Scatter Plot



3D Scatter Plot

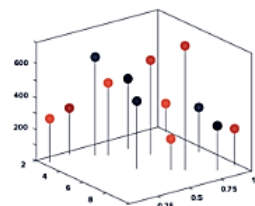
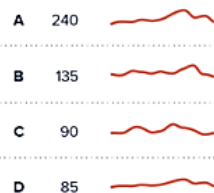


Fig. 6. Scatter and 3D scatter chart examples

- Sparkline (shown in fig. 7). Might be also shown in a form of column charts.

Sparkline



Column Sparkline

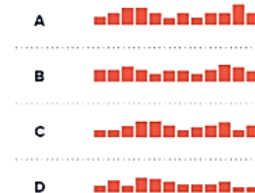


Fig. 7. Sparkline and column sparkline examples

- Gauge (shown in fig. 8). Can be displayed in a form of the angular or a solid chart.

Angular Gauge



Solid Gauge Chart



Fig. 8. Angular and solid gauge examples

- Pie chart (shown in fig. 9).

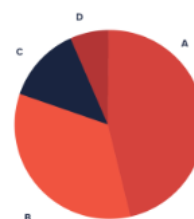


Fig. 9. Pie chart example

Various data visualization graphs and charts ordered by their informativeness are shown in table 1 [15].

Table 1 – Charts ordered by their informativeness

Chart	Estimated informativeness
Bar	53%
Line	46%
Bullet	25%
Scatter	23%
Sparkline	22%
Gauge	12%
Pie	10%

Mapping between data types and graphs and charts is shown in table 2 [15].

Table 2 – Charts ordered by their informativeness

Data type	Charts and graphs
Composition	Bar, Pie
Categories	
Comparison	Line, Scatter
Distribution	
Single value	Number, Sparkline
Difference between an actual and a target value	Bullet, Gauge

Research [17] proposes mathematical models used to define optimal set of charts used to visualize KPIs data on a dashboard. Similar problem is also solved with the help of fuzzy semantic networks [12]. However, the dashboard design mostly depends on users' preferences, which might be quite subjective. It means that various users need to see the same set of KPIs displayed on a dashboard but shown using different charts according to the user's preferences.

Model of the dashboard design. Since each KPI shows a value of the specific data type, we can map KPIs to data types. We can also map data types to possible visualization tools.

These relationships might be formalized using the following matrices:

$$\mathbf{A} = (a_{ij})_{i=1,j=1}^{n,p}, \mathbf{B} = (b_{jk})_{j=1,k=1}^{p,q}. \quad (1)$$

Where n is the number of KPIs, p is the number of data types, and q is the number of visualization tools. Both matrices \mathbf{A} and \mathbf{B} contain only binary values that shows presence or absence of relationship between KPIs and data types (1), as well as between data types and visualization tools respectively:

$$\begin{aligned} a_{ij} &\in \{0,1\}, i = \overline{1,n}, j = \overline{1,p}, \\ b_{jk} &\in \{0,1\}, j = \overline{1,p}, k = \overline{1,q}. \end{aligned} \quad (2)$$

Moreover, each KPI might be assigned to a single data type (2), while the data type might be represented using several visualization tools:

$$\begin{aligned} \sum_{j=1}^p a_{ij} &= 1, i = \overline{1,n}, \\ \sum_{k=1}^q b_{jk} &\geq 1, j = \overline{1,p}. \end{aligned} \quad (3)$$

It is required to multiply matrices \mathbf{A} and \mathbf{B} in order to trace relationships between KPIs and visualization tools that might be used to display values of these KPIs (3):

$$\mathbf{C} = \left(c_{ik} = \sum_{l=1}^p a_{il} \cdot b_{lk} \right)_{i=1,k=1}^{n,q}. \quad (4)$$

Where elements of the matrix \mathbf{C} are binary values as well (4), $c_{ik} \in \{0,1\}$, $i = \overline{1,n}$, $k = \overline{1,q}$.

Various users might be interested in analysis of various KPIs according to their roles in business processes and decisions they have to make according to their roles. Therefore, existing mapping of KPIs to visualization tools should be appended with the mapping of user roles in business processes to KPIs.

Therefore matrices \mathbf{A} , \mathbf{B} , and consequently the \mathbf{C} , should be defined for each t -th user role, $t = \overline{1,s}$:

$$\begin{aligned} \mathbf{A}^t &= (a_{ij}^t)_{i=1,j=1}^{n,p}, \mathbf{B}^t = (b_{jk}^t)_{j=1,k=1}^{p,q}, \\ \mathbf{C}^t &= (c_{ik}^t)_{i=1,k=1}^{n,q}. \end{aligned} \quad (5)$$

There are no general recommendations that might be applied to any user with specific preferences (5). Hence, the only possible way to solve this problem is to obtain user's suggestions on KPIs ranks for each user role. The expert judgment procedure will not be considered in this study itself. We only consider that weights of each KPI for each corresponding user role are previously obtained:

$$\mathbf{w}_t = \begin{pmatrix} w_{t1} \\ \vdots \\ w_{ti} \\ \vdots \\ w_{tn} \end{pmatrix}, t = \overline{1,s}. \quad (6)$$

Where s is the number of user roles. KPIs weights w_{ti} should be normalized (6), i.e. $w_{ti} \in [0,1]$, $t = \overline{1,s}$, $i = \overline{1,n}$.

Weights of visualization tools λ_k , $k = \overline{1,q}$ might be defined as following (Table 3) by using the normalization of values shown in Table 1.

Table 3 – Weights of graphs and charts

k	Chart	Estimated informativeness	λ_k
1	Bar	53%	1.00
2	Line	46%	0.87
3	Bullet	25%	0.47
4	Scatter	23%	0.43
5	Sparkline	22%	0.42
6	Gauge	12%	0.23
7	Pie	10%	0.19

It is expected that a dashboard might be launched on the devices with various screen resolutions. Thus we have to provide the adaptive dashboard. For this purpose, the screen width should be divided into 12 columns (fig. 10) according to Bootstrap framework [18].

1	1	1	1	1	1	1	1	1	1	1	1
2		2		2		2		2		2	
3			3			3			3		
4				4				4			
6										6	

Fig. 10. Screen divided into 12 columns according to Bootstrap

Each visualization tool takes place of a certain width on a dashboard. Thus, it is required to introduce the vector of sizes for each visualization tool l_k , $k = \overline{1,q}$. Moreover, for each t -th user role it is required to define the number of

rows r_t , $t = \overline{1, s}$ in which graphs and charts should be placed. It is well known that human can concentrate only on a limited number of things at once, therefore, the limit number of KPIs required to be placed on a dashboard for the t -th user role $\bar{v}_t \geq 0$, $t = \overline{1, s}$ should be introduced.

The mathematical model of the optimization problem that should be solved to provide recommendations on a dashboard's design is the following:

$$\begin{aligned} \sum_{t=1}^s \left[\sum_{i=1}^n \sum_{k=1}^q (w_{ti} \cdot c_{ik}^t \cdot \lambda_k \cdot v_{ik}^t) \right] &\rightarrow \max, \\ \sum_{i=1}^n \sum_{k=1}^q v_{ik}^t &\leq \bar{v}_t, t = \overline{1, s}, \\ \sum_{i=1}^n \sum_{k=1}^q v_{ik}^t \cdot l_k &\leq 12 \cdot r_t, t = \overline{1, s}, \\ \sum_{k=1}^q v_{ik}^t &\leq 1, i = \overline{1, n}, t = \overline{1, s}, \\ v_{ik}^t &\in \{0, 1\}, k = \overline{1, q}, i = \overline{1, n}, t = \overline{1, s}. \end{aligned} \quad (7)$$

Where s is the number of user roles, n is the number of KPIs, q is the number of used visualization tools, w_{ti} describes mapping between t -th user role and i -th KPI, $\{\lambda_k\}$ is the normalized vector of priorities of visualization tools, $\{v_t\}$ is the restrictions vector of the number of KPIs that might be shown on a dashboard, $\{c_{ik}\}$ is the binary matrix that demonstrates possibility of i -th KPI to be displayed using k -th visualization tool, and $\{v_{ik}^t\}$ is the result binary matrix, which provides recommendations on which k -th visualization tool should be used to display i -th KPI on a dashboard that corresponds to t -th user role.

There is also situations are possible, where the same user might have multiple roles at the same time, $t^* = \{t^o\}$, $o \in [1, s]$. In this case we need to select such matrix V^* that does not restrict user access to necessary information. Hence the binary matrix that describes indicators and data visualization tools for the user with multiple roles:

$$V^* = \max_{\substack{o \in [1, s] \\ i = \overline{1, n}}} (v_{ik}^t) \cdot \lambda_k, k = \overline{1, q}. \quad (8)$$

Since the optimization variables (8) might take only 0 or 1 values, proposed mathematical model (7) describes the combinatorial optimization problem, which recalls the 0/1 knapsack problem [19] with additional restrictions.

Software solution for the dashboard design. A branch-and-bound method is used for several of NP-hard problems, such as the 0/1 knapsack problem [19]. Therefore, the branch-and-bound method might be used to solve the introduced optimization problem as well.

Developed software uses Google OR-Tools library, which mathematical programming solver class MPSolver implements the branch-and-bound method [20].

Besides the optimization library, the software uses MySQL database management system in order to maintain the database of related data about the user roles, business processes, KPIs, graphs and charts, and the results of the dashboard design. The structure of such database is shown

in fig. 11. Spring Boot framework is used to simplify and accelerate development of the Java-based web application, which fronted part is created using Vue.js and Bootstrap frameworks.

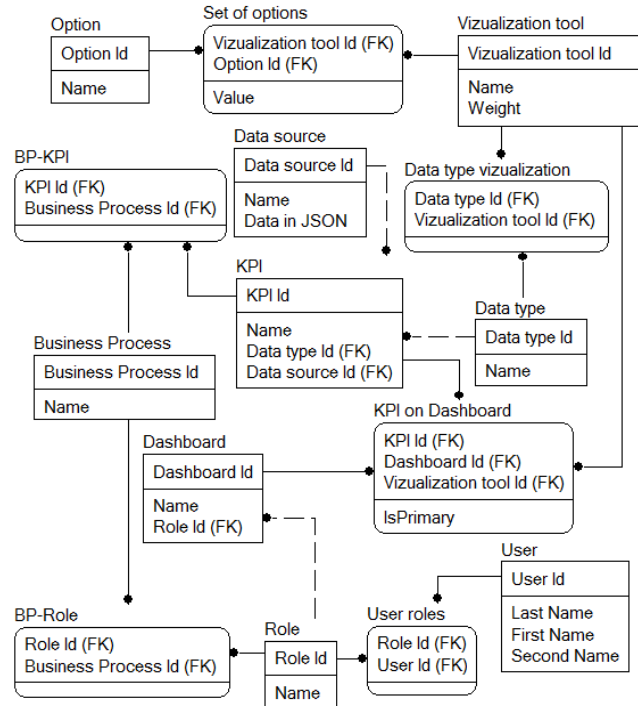


Fig. 11. Database structure

The deployment diagram of the developed software solution is shown below (fig. 12).

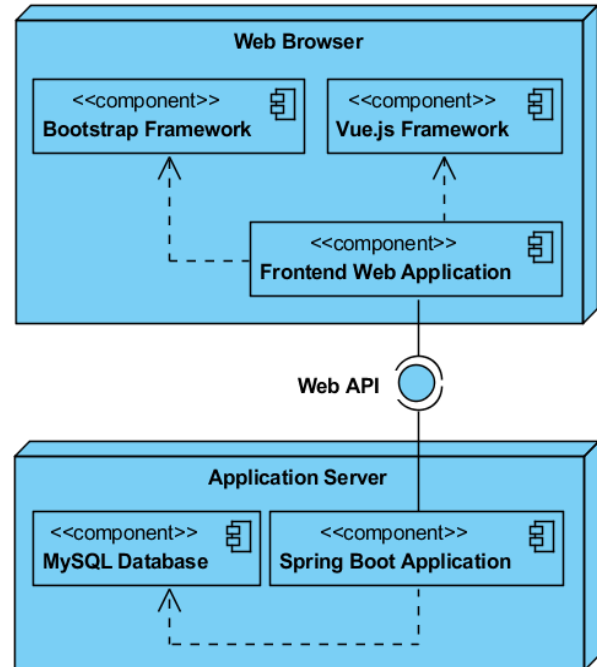


Fig. 12. Deployment diagram of the software solution

Process of the developed software solution usage includes three general activities shown in fig. 18 with the help of the IDEF0 process diagram. The first step includes formulation of the input information for the dashboard design. At first it is required to create a user role (fig. 13).

Fig. 13. Creation of the user role

Then it is necessary to create a business process to which this user role should be assigned (fig. 14).

Fig. 14. Creation of the business process

Finally, it is required to create KPIs that are related to the business process (fig. 15):

- KPI “Return on Assets” shows distribution data.
- KPI “Net Income” communicates single value.
- KPI “Operating Expenses” is intended to display difference between actual and target values.

Fig. 15. Creation of the KPI

On the second step all restrictions for the dashboard design should be provided (fig. 16). Weights (6), numbers of rows and KPIs to be placed on the dashboard are set.

Fig. 16. Configuration of the restrictions

After all the input information and restrictions are specified, it is vital to provide a link to a data source that returns data arrays in a form of JSON documents (Java Script Object Notation) that are easy readable by humans and computers (fig. 17).

Fig. 17. Configuration of the data source

Suggestions on the dashboard design are obtained in a form of a generated dashboard (fig. 22) that corresponds to the input information (fig. 13–15) and restrictions (fig. 16) with respect to the optimization problem (7).

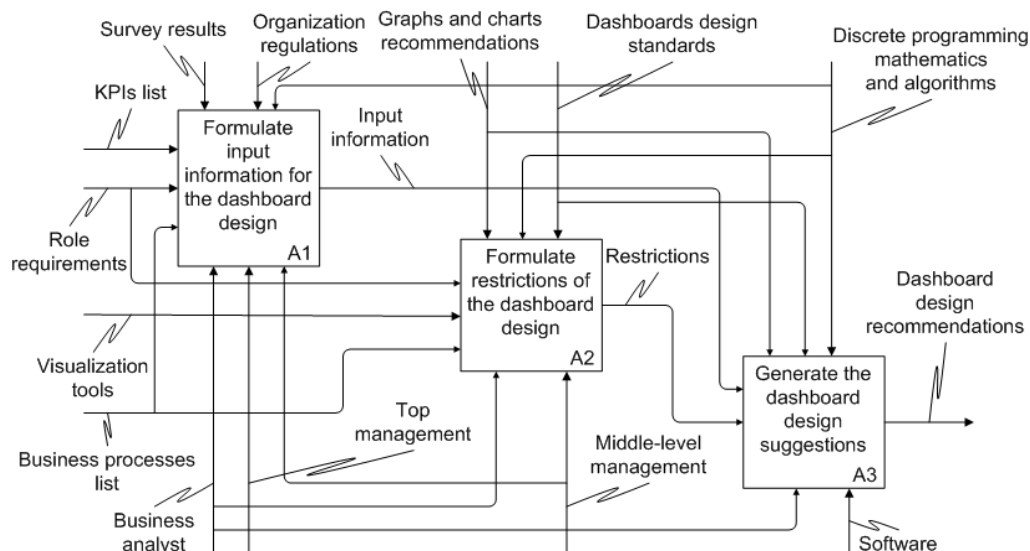


Fig. 18. Process of the developed software solution usage

As it is demonstrated in fig. 22, generated dashboard consists of graphs and charts that best fit to data arrays represented by considered KPIs:

- KPI “Return on Assets” is displayed first by using a line chart.
- KPI “Net Income” is displayed second by using a sparkline indicator.
- KPI “Operating Expenses” is displayed third by using a gauge indicator.

Research results and discussion. Validation of the proposed model and the software solution is performed by emulation of user’s requirements.

The normalized vector of user’s requirements and restrictions on indicators, which should be included in a dashboard, correspond to the values shown in fig. 19. It means that user needs the dashboard that displays a single KPI “Return on Assets”.

Fig. 19. User’s requirements for a dashboard with one indicator

Obtained dashboard is demonstrated in fig. 20. It is shown that user’s request for the dashboard with a single KPI “Return on Assets” is fulfilled.

It is also possible to replace a visualization tool for the displayed KPI. Thus, the line chart (fig. 20) might be swapped to the scatter chart (fig. 21).

Then let us consider a situation, where user needs to generate the dashboard with all available KPIs (fig. 23). After weights and restrictions are specified, the dashboard design is provided (fig. 25).

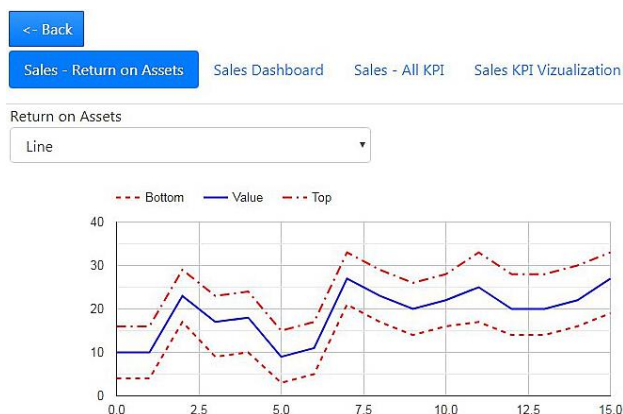


Fig. 20. Generated recommendations for the dashboard design with a single indicator

Modified dashboard is shown below (fig. 21).

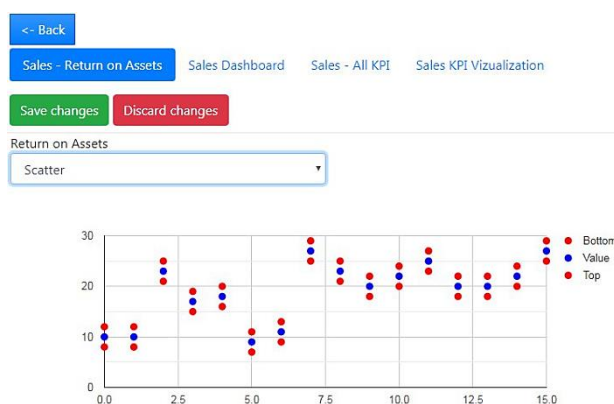


Fig. 21. Result of indicator’s replacement

Fig. 25 demonstrates that the software generated the dashboard, which contains 3 of 5 possible KPIs. Such recommendations on the dashboard design were obtained because the restriction for the limit number of rows was not changed. Therefore, the optimal set of indicators was selected according to the model (7).

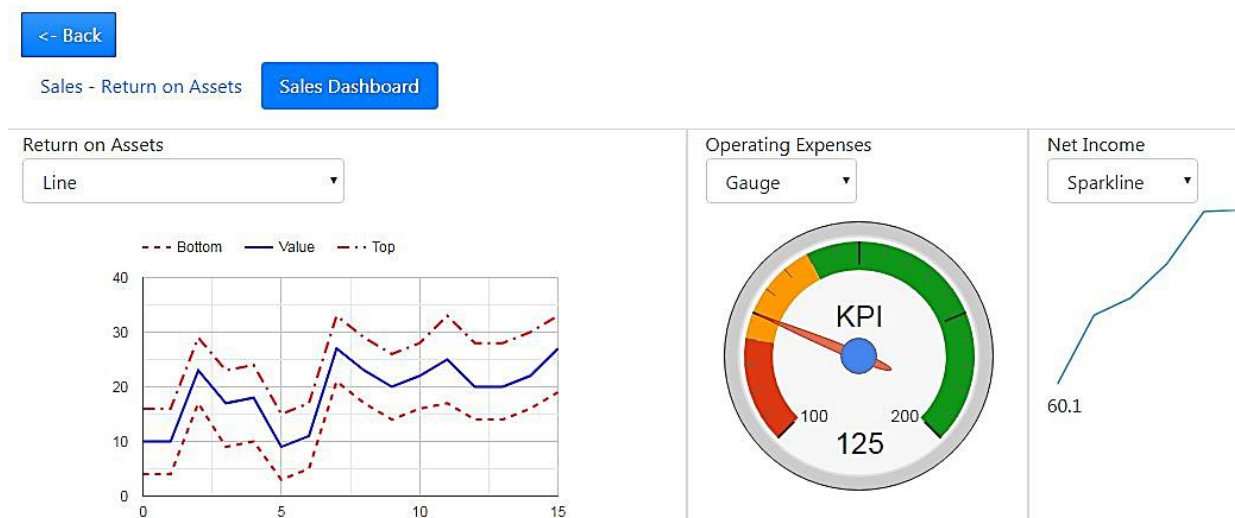


Fig. 22. Generated dashboard based on provided input information and restrictions

Fig. 23. User's requirements modification

However, it might be necessary to display all KPIs on the same dashboard. For this purpose it is required to update the limit number of rows (fig. 24).

Fig. 24. Increased limit number of records

Extended dashboard is shown in fig. 27. It is shown that generated recommendations (fig. 27) satisfy user's requirements – now the dashboard contains all available KPIs:

- KPI "Revenue".
- KPI "Return on Assets".
- KPI "Operating Expenses".
- KPI "Net Income".
- KPI "Growth in Customer Base".

It is demonstrated (fig. 27), that sequence of KPIs is rearranged in compare to the previously generated result (fig. 25). This is happened because of the different sizes of used graphs and charts that correspond to the Bootstrap layout grid.

Besides recommendations on the dashboard design, developed software demonstrates numerical results of the solution of the optimization problem (7). Such results for the dashboards shown in fig. 25 and 27 are demonstrated below (fig. 26).

$1.0 * 0.47 = 0.47$	$1.0 * 0.47 = 0.47$
$1.0 * 0.23 = 0.23$	$1.0 * 0.23 = 0.23$
$x_{01} = 0.0$	$x_{01} = 1.0$
$x_{03} = 0.0$	$x_{03} = 0.0$
$x_{10} = 1.0$	$x_{10} = 1.0$
$x_{16} = 0.0$	$x_{16} = 0.0$
$x_{24} = 1.0$	$x_{24} = 1.0$
$x_{34} = 0.0$	$x_{34} = 1.0$
$x_{42} = 1.0$	$x_{42} = 1.0$
$x_{45} = 0.0$	$x_{45} = 0.0$
Objective value = 1.89	Objective value = 3.18

Fig. 26. Solutions of the optimization problem (7)

Optimization results (fig. 26) demonstrate how the recommended set of indicators was extended from 3 to 5 KPIs. At the same time, the dashboard's informativeness has been improved from 1.89 to 3.18 (objective value of the optimization problem). However, the number of KPIs displayed on the dashboard has been increased as well,

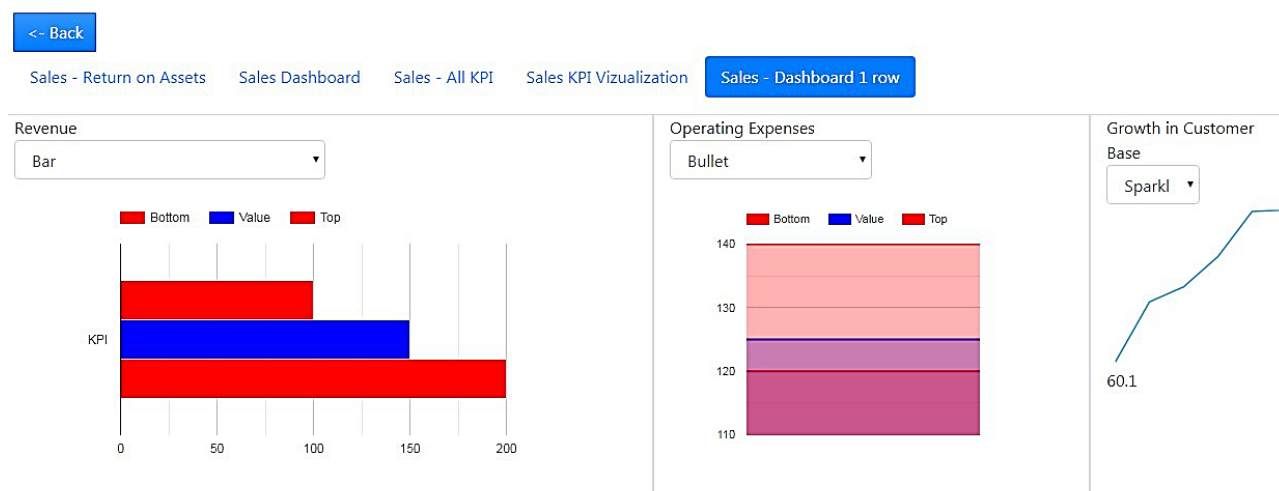


Fig. 25. Generated dashboard with a single row

which means that it is harder to place such dashboard in a small place, e.g. on a smart phone display.

Outlined results (fig. 19–27) show validation of the proposed software solution.

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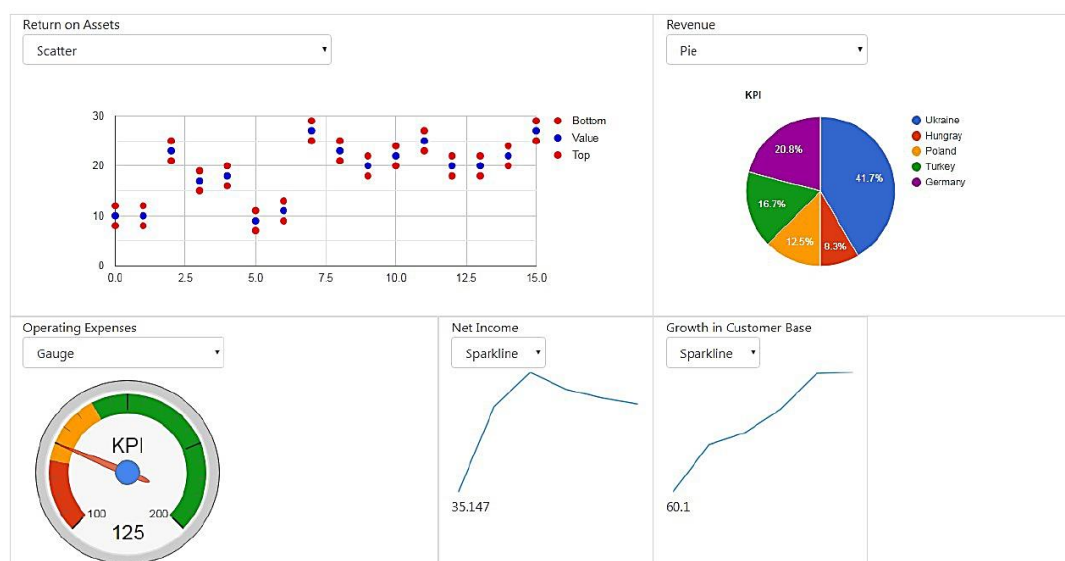


Fig. 27. Generated dashboard with two rows

Conclusion. In this paper we have proposed a model and a software solution for the dashboard design for the business process status analysis. Proposed model is based on the 0/1 knapsack optimization problem but it was extended with some domain-specific restrictions such as number of KPIs to be displayed on a dashboard or a limit of a certain screen on which the dashboard is supposed to be placed. The dashboard design model (7) is used to map KPIs related to a certain business processes, which at the same time belongs to a specific user role, to the various visualization tools, such as graphs and charts, with respect to the introduced restrictions on size and user preference. The software that implements proposed model is created using modern backend and frontend technologies, so it can be easily deployed and maintained. Process of its usage is outlined, its validation is shown, and the obtained results in a form of the generated dashboards are discussed.

Future research in this field includes integration with existing BI software, such as Microsoft Analysis Services and Power BI, Tableau, QlikView or other tools, in order to make the suggested dashboards more independent on used tools, accessible, interoperable, and exchangeable.

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